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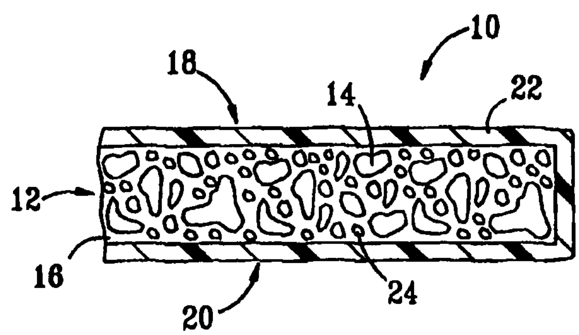
(54) Title: HIGH STRENGTH FLEXIBLE MAGNETIC PAD

(57) Abstract

Flexible magnetic pads (10) having a magnetic core (12) dispersed in a flexible polymeric outer layer (22) having oppositely facing, single pole surfaces (18, 20) with increased magnetic strength and penetration depth are disclosed that comprise a magnetic core (12) having from about 40 to about 60 weight percent of a first ferromagnetic material (14) such as Nd–Fe–B having a predetermined average particle size ranging from about 25 to about 325 microns, and at least one other ferromagnetic filler material (24) having a smaller predetermined average particle size such that the smaller particles fill a substantial number of the interstices between the particles of the first ferromagnetic material. A preferred ferromagnetic filler material is from about 5 to 15 weight percent strontium ferrite having an average particle size of about 50 microns.



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HIGH STRENGTH FLEXIBLE MAGNETIC PAD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to flexible magnetic pads having a magnetic core comprising a particulate magnetic material embedded or dispersed in a substantially continuous phase of a flexible, most preferably elastomeric, polymeric material. More particularly, the invention preferably relates to a high strength flexible magnetic pad having a magnetic core material comprising powdered neodymium-iron-boron or neodymium-cobalt-iron in combination with at least one other powdered iron alloy component having a smaller average particle size so that the smaller particles occupy the interstices between the particles of magnetic core material. The magnetic pads of the invention are believed to be especially useful for therapeutic applications and for other applications where a flexible pad having a strong magnetic field with oppositely facing, single pole surfaces is desired.

2. Description of Related Art

It is well known that magnetic fields such as those created by permanent magnets can have therapeutic effects on the human body. The therapeutic effects are believed to result from increased blood circulation in the area of the body subjected to the influence of the magnetic field. In recent years the use of rigid, permanent magnets in such therapeutic applications has diminished due to the availability of magnetic pads that are flexible enough to conform substantially to a portion of the body surface without causing discomfort to the

user. Others have devoted considerable effort to creating magnetic pads having an alternating magnetic pole orientation of optimal design to supposedly induce electrical currents within the treatment area irrespective of the orientation of the blood vessels. As an example, magnetic pads have been developed with alternating magnetic poles arranged in spirals, checkerboard patterns, rings, radial sectors, and the like.

While flexible magnetic pads having alternating magnetic pole designs are effective at inducing electrical currents within a targeted treatment area, they have several drawbacks. Magnetic field strength decreases much more rapidly per unit distance from a magnetic pad having alternating magnetic poles than from one having single pole surfaces. This effect reduces the depth of penetration of the magnetic field into the targeted treatment area, producing only surface effects. To increase penetration depth, stronger magnets need to be used or additional percentages of magnetic material must be suspended within the pad, which can make the magnetic pad heavier and less flexible. Alternating magnetic pole designs are also believed to reduce the effect of the Lorentz forces on charged particles within the blood vessels. Under the influence of a directionally changing magnetic field, charged particles within the treatment area are first accelerated, then slowed, as they travel across boundaries of adjacent zones having different magnetic polarities.

Plastic magnet compositions containing niobium-iron-boron magnetic powder surface-treated with a polyorganosiloxane resin are disclosed in Japanese Publication No. JP3188601, dated August 16, 1991.

Flexible magnetic pads for therapeutic use containing magnetized neodymium-iron-boron particles in silicone rubber are disclosed in International Publication No. WO 95/16473.

Flexible magnetic pads for therapeutic use having alternating north and south magnetic poles on a single surface are disclosed in U.S. 4,549,532. The pads disclosed therein contain permanent magnetic particles of unspecified

size, such as barium ferrite or strontium ferrite, embedded in a rubbery-flexible synthetic material.

A reversible magnetic therapeutic device for human or animal use having a two-sided flexible wrapper and a plurality of magnets supported in pockets in the wrapper, with all the north poles on one side of the wrapper and all south poles on the opposite side, is disclosed in U.S. 4,587,956.

Other magnetic therapeutic devices are disclosed in U.S. 3,943,912 and 4,489,711.

SUMMARY OF THE INVENTION

I have now discovered that magnetic pads having a powdered particulate magnetic core surrounded by a flexible polymeric material and having significantly improved magnetic strength and penetrating capability for therapeutic use can be made by incorporating into the magnetic core from about 40 to about 60 weight percent of a first ferromagnetic material such as neodymium-iron-boron or neodymium-cobalt-iron having a particle size ranging from about 25 to about 325 microns, and primarily about 200 microns, and a lesser amount, most preferably about 15 weight percent, of at least one other iron alloy filler material having a smaller predetermined average particle size small enough that the smaller particles fill a substantial number of the interstices between the particles of the first ferromagnetic material.

According to one preferred embodiment of the invention, the subject magnetic pads contain from about 5 to about 15 weight percent of a ferromagnetic filler material such as strontium ferrite, barium ferrite, or strontium barium ferrite, most preferably having an average particle size of about 50 microns, plus or minus about 7 microns.

According to another preferred embodiment of the invention, the subject magnetic pads have oppositely facing, single pole surfaces.

According to another preferred embodiment of the invention, the magnetic core of the subject magnetic pads is encapsulated within a layer of polymeric material having a thickness of from about 25 microns up to about 10 mils, and most preferably about 5 mils. The use of an encapsulating polymeric surface layer reduces the likelihood of discoloration or reaction due to contact between the skin (or perspiration) and the metallic components of the magnetic core.

According to a particularly preferred embodiment of the invention, the subject magnetic pads will maintain a constant field strength ranging from about 130 to about 320 gauss over hardness values (Shore A Durometer) ranging

from about 10 to about 80, and will pass a 1/8 Curved Mandrel Test (Dow Corning Corporate Test Method 0895).

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is further described and explained in relation to the following figures of the drawings wherein:

FIG. 1 is a top perspective view of a flexible magnetic pad of the invention; and

FIG. 2 is an enlarged partial cross-sectional view taken along line 2--2 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, magnetic pad 10 is desirably sufficiently flexible to enable it to drape over and fit any external contour of the human body, such as a knee, arm or finger, and thereby provide therapeutic relief from various pains and disorders. The magnetic pad is also desirably elastic to facilitate elongation or stretching when wrapped around joints, although substantial elasticity is not necessarily required. It should be appreciated that FIGS. 1 and 2 are simplified for illustrative purposes and are not drawn to scale. Although depicted in FIG. 1 in a generally circular configuration, magnetic pad 10 can be made rectangular or in another regular or irregular shape particularly well suited for a particular application such as, for example, use around an ankle or elbow.

Referring to FIG. 2, magnetic pad 10 preferably comprises magnetic core 12 further comprising a plurality of ferromagnetic particles 14, 24 disposed inside a substantially continuous phase of an elastomeric polymer 16. The ferromagnetic particles 14, 24 are preferably distributed substantially evenly across magnetic pad 10 between top and bottom surfaces 18, 20, respectively, as discussed below. In this preferred embodiment of the invention, sealing layer 22 is made of the same or a different polymeric material and desirably encapsulates magnetic core 12. Magnetic pad 10 is preferably magnetized so that top and bottom surfaces 18, 20, respectively, each have an oppositely facing single magnetic pole.

A preferred polymer 16 for use as the substantially continuous elastomeric phase of magnetic core 12 and for sealing layer 22 is silicone rubber, which is compatible with human skin (*i.e.*, hypoallergenic) and conformable to the body surface. If desired, the polymeric materials used within magnetic core 12 and as sealing layer 22 may be different in kind, or may be similar polymers with different durometers to improve pad comfort or flexibility. Silicone rubber provides magnetic pad 10 with desired chemical and temporal stability, and also contributes to the elasticity of magnetic pad 10.

Silicone rubbers usable as polymer 16 include polysiloxane vinyl end-blocked polymers and polysiloxane hydroxy end-blocked polymers of differing viscosities, *i.e.*, low or high consistency silicone. Low consistency silicone is a flowable material before curing and can be poured into molds or rolled into sheeting. High consistency silicone is a non-flowable solid that is mixed with metal powder and catalyzed on a two roll mixer and then forced into molds under very high pressure in transfer presses. In the subject magnetic pads, the silicone itself serves as the carrier of the ferromagnetic powder, and is not used just as a binder to hold the metallic particles to the carrier. According to one particularly preferred embodiment of the invention, magnetic pad 10 will comprise from about 35 up to about 40 weight percent of silicone polymer, although a lesser or greater amount of polymeric material can also be used satisfactorily depending upon factors such as the particular polymer(s), the type and loading of the ferrogmagnetic powders, the desired flexibility, the thickness of the sealing layer, and the intended use. Silicones useful in making the magnetic pads of the invention are commercially available, for example, from Dow Corning, GE, Wacker Silicones Inc., and others.

The ferromagnetic particles embedded in magnetic core 12 will preferably have a high magnetic retentivity with a residual induction of over 0.8 T (making ferrites inutile) to produce the desired magnetic field necessary to provide therapeutic relief in a flexible magnetic pad 10. Particles 14 preferably comprise from about 40 to about 60 weight percent of magnetic pad 10, with a particle size ranging from about 25 to about 325 microns, a size large enough to act as permanent magnets yet small enough to fit within magnetic core 12 and afford the necessary flexibility. In one particularly preferred embodiment, particles 14 are Neodymium-Iron-Boron ($Nd_2Fe_{14}B$) particles having an average particle size of about 200 microns. Such particles are commercially available as Magnequench MQP-B powder, having a residual inductance of about 0.8-0.84 T. Magnetic core 12 preferably further comprises from about 5 to about 15 percent by weight of magnetic pad 10 of particles 24 of a ferromagnetic filler

material having an average particle size smaller that the average particle size of particles 14, most preferably about 50 microns, to fill the interstices between particles 14 within magnetic core 12. Strontium ferrite, having a density of about 4.9 g/cm^3, is a preferred particulate filler material. One commercially available source of powdered strontium ferrite is The Hoosier Magnetics Group. Other powdered iron alloy materials useful as the ferromagnetic filler material include, for example, barium ferrite and strontium barium ferrite.

Magnetic core 12, comprising particles 14, 24 dispersed throughout a matrix of polymeric material such as silicone polymer, is preferably from about 1.25 to about 6.25 mm thick, and most preferably from about 1.5 to about 2 mm thick. Sealing layer 22, again preferably a silicone polymer as previously described, surrounds magnetic core 12 to prevent particles 14, 24 at the surface of magnetic core 12 from flaking off the surface and to prevent the metallic particles from contacting the skin of a user. The thickness of sealing layer 22 can range from about 25 microns up to about 10 mils or more, and a sealing layer having a thickness of about 5 mils is particularly preferred.

Preferably, magnetic core 12 of magnetic pad 10 is formed by airless mixing 40-60% by weight of the Neodymium-Iron-Boron particles 14 and 5-15% by weight of the strontium ferrite particles 24 in a one or two part silicone rubber material 16, including minor effective amounts, generally less than one weight percent, of any suitable, conventional, well known catalyst and cross-linking agent. A minor amount, such as about one weight percent, of a pigment such as titanium dioxide pigment, can also be added if desired. The resulting mass is then formed into sheets, preferably 1.5 to 2 mm thick as described above, either through calendering or a continuous casting process, or is poured into appropriately dimensioned molds. Backing sheets, such as Mylar® sheeting material, may be utilized as is known in the art to provide a nonadherent surface for maintaining the desired thickness of magnetic core 12 throughout the curing process. Depending upon the forming process, the core layer 14 is either platinum or peroxide cured, with the continuous casting platinum 120-

150°C dry heat cure being preferred over the steam peroxide cures used with calendering and molding.

After curing, the magnetic core 12 is preferably cut into shapes and sizes desired for the intended application. Typically, magnetic core 12 will be cut into either circular or rectangular patterns of differing dimensions dependent upon the area of desired treatment, but it is understood that the magnetic pad 10 can be cut to any size or shape for custom applications.

Once cut, magnetic core 12 is preferably surrounded by and encapsulated within sealing layer 22 by coating magnetic core 12 with additional silicone rubber material. Magnetic pad 10 is subsequently introduced into the air-gap of an electromagnet capable of producing a magnetic flux density in excess of 2.5 T to impart a magnetic remanent field to particles 14, 24. When particles 14 are Neodymium-Iron-Boron, the resulting magnetic field measured at 6.35 mm from the magnetic pad 10 will exceed 2 mT, it being understood that increased percentages of particles 14 will result in higher remanent fields, as will the inclusion of particles 24 as described above.

Magnetic pad 10 is desirably magnetized in a known manner to cause top surface 18 of the pad to be one magnetic pole and bottom surface 20 of the pad to be the opposite magnetic pole, thereby avoiding the alternating magnetic poles so prevalent in the prior art.

Examples

To further demonstrate the efficacy of the invention, magnetic pads were prepared as described above using eight different compositions, all comprising Magnequench MQP-B powder as the magnetic core. Two compositions contained 60% and 80% by weight, respectively, magnetic core material with no ferromagnetic filler material. The other six compositions contained 50 weight percent Magnequench MQP-B powder as the magnetic core and 30 weight percent of a powdered iron alloy as shown in the table below. All pads passed the flexibility test as stated above. The pads were magnetized and six samples were prepared for each composition. The magnetic field strengths were then

measured for each of the six samples of each composition, and the results are reported in Table 1 below.

TABLE 1

COMP. NO.	MQP-B (wt. %)	FILLER MATERIAL	FILLER (wt. %)	MAGNETIC STRENGTH (gauss)
1	60	None	None	148-205
2	80	None	None	190-235
3	50[a]	Sr/Fe	30	134-165
4	50[b]	Sr/Fe	30	146-171
5	50[c]	Ba/Fe	30	143-188
6	50[d]	Sr/Fe	30	163-193
7	50[e]	Sr/Fe	30	171-205
8	50[f]	Sr/Ba/Fe	30	260-317

a. Hoosier 402
b. Hoosier 406
c. Hoosier 410
d. Hoosier 170
e. Hoosier 181
f. Hoosier 130

In use, magnetic pad 10 is placed on a portion of the body needing treatment and secured in place by elastic bands, bandages, band-aids or in other known ways (not shown), with the north pole side (labeled as such on a manufactured pad) of the magnetic pad 10 preferably being placed closest to the body. An adhesive strip can also be attached to the magnetic pad 10 to facilitate securing the pad to the treatment area. Due to the flexibility of the magnetic pad 10, the pad will conform to the treatment area regardless of the size or angular orientation of the body part. The magnetic field generated by the magnetic pad 10 penetrates into the body and is believed to impart a Lorentz

force on the numerous charged particles flowing within the blood vessels causing increased blood flow through the treatment area.

Use of magnetic pad 10 is believed to produce beneficial physiological effects. Generally, the magnetic pad 10 increases the therapeutic ability of magnetic field's by providing a form-fitting device having single magnetic poles on each surface. For example, providing a single pole magnetic device increases the penetration of the magnetic field into the treatment area as compared to alternating magnetic pole pads of equal magnetic strength as measured at their respective surfaces. Moreover, the single pole field maximizes the Lorentz forces experienced within the treatment area. Under a directionally changing magnetic field, the Lorentz forces would alternate as well, thereby causing the charged particles within the body to be pushed in one direction and then be suddenly slowed and pushed in the opposite direction as the particles move through the field.

The flexibility of the magnetic pad 10 provides additional physiological advantages. By being form-fitting, the magnetic pad 10 provides magnetic field penetration over a greater percentage of the treatment area as it can be conformed around elbows and other curved body parts. Thus in treating a sore shoulder, the magnetic pad 10 will lie smoothly against the front, top and back of the shoulder, as well as along the neck and upper arm, thereby penetrating the entire area. The magnetic pad 10 can also be used for even the smallest human extremities and cylindrical body parts such as fingers and ankles. In addition, such joints do not have to be immobilized during treatment as the magnetic pad 10 is desirably elastic, facilitating its use during exercise or other movement. Further, specially configured magnetic pads are not necessary for each differently shaped treatment area as the flexibility of the magnetic pad 10 allows it to form-fit to all contours of the human body. The subject invention is also believed to have industrial applicability.

It is also understood that variations may be made in the present invention without departing from the spirit and scope of the invention. For

example, the ferromagnetic particles 14 need not be Neodymium-Iron-Boron particles, so long as they provide a residual induction of over 0.8 T. Further, those skilled in the art will recognize that the percentage of particles 14, 24 required in magnetic core 12 can be reduced with increased residual induction. By decreasing such percentage, the flexibility of the magnetic pad 10 can be further increased. Moreover, besides being cut into the shapes described above, the magnetic pad 10 can be cut into specially designed shapes, such as to fit within a shoe.

In certain instances some features of the invention may be employed without a corresponding use of other features. Other alterations and modifications of the invention will likewise become apparent to those of ordinary skill in the art upon reading the present disclosure, and it is intended that the scope of the invention disclosed herein be limited only by the broadest interpretation of the appended claims to which the inventors are legally entitled.

CLAIMS:

1. A flexible magnetic pad comprising:
   (a) a magnetic core having from about 40 to about 60 percent by weight of the pad of a first particulate ferromagnetic material having a particle size ranging from about 25 to about 325 microns and an average particle size within that range, and from about 5 to about 15 percent by weight of the pad of a particulate ferromagnetic filler material having an average particle size smaller than the average particle size of the first particulate ferromagnetic material, dispersed throughout a substantially continuous polymeric phase comprising from about 35 to about 40 percent by weight of the pad of a flexible polymeric material; and
   (b) a coating around the magnetic core, the coating comprising a flexible polymeric material and having a thickness ranging from about 25 microns to about 10 mils.

2. The flexible magnetic pad of claim 1 wherein the average particle size of the first particulate ferromagnetic material is about 200 microns.

3. The flexible magnetic pad of claim 1 wherein the average particle size of the particulate ferromagnetic filler material ranges from about 43 to about 57 microns.

4. The flexible magnetic pad of claim 3 wherein the average particle size of the particulate ferromagnetic filler material is about 50 microns.

5. The flexible magnetic pad of claim 1 wherein the first particulate ferromagnetic material is an alloy of neodymium, iron and boron.

6. The flexible magnetic pad of claim 1 wherein the first particulate ferromagnetic material is an alloy of neodymium, cobalt and iron.

7. The flexible magnetic pad of claim 1 wherein the particulate ferromagnetic filler material is strontium ferrite.

8. The flexible magnetic pad of claim 1 wherein the particulate ferromagnetic filler material is strontium ferrite.

9. The flexible magnetic pad of claim 1 wherein the particulate ferromagnetic filler material is barium ferrite.

10. The flexible magnetic pad of claim 1 wherein the particulate ferromagnetic filler material is strontium barium ferrite.

11. The flexible magnetic pad of claim 1 wherein the flexible polymeric material of the magnetic core is elastomeric.

12. The flexible magnetic pad of claim 11 wherein the flexible polymeric material of the magnetic core comprises silicone.

13. The flexible magnetic pad of claim 1 wherein the flexible polymeric material of the coating is elastomeric.

14. The flexible magnetic pad of claim 13 wherein the flexible polymeric material of the coating comprises silicone.

15. The flexible magnetic pad of claim 1 wherein the flexible polymer is cured using a curing agent.

16. The flexible magnetic pad of claim 1 having a residual induction over about 0.8 T.

17. The flexible magnetic pad of claim 1 having top and bottom surfaces, wherein the first particulate ferromagnetic material and the particulate ferromagnetic filler material are magnetized to produce opposite magnetic poles on the respective top and bottom surfaces.

18, The flexible magnetic pad of claim 1 wherein the flexible polymeric material of the magnetic core and the flexible polymeric material of the coating are different.

19. The flexible magnetic pad of claim 1 wherein the coating has a thickness of about 5 mils.

FIG. 1

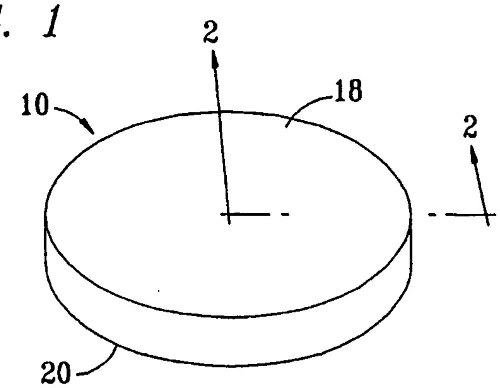
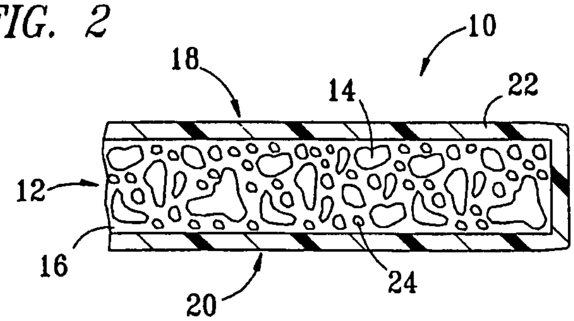


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/07524

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 09516473 A (MTI, INC.) 22 June 1995, see entire document.	1-19
Y	US 5,567,757 A (SZCZEPANSKI) 22 October 1996, see entire document.	1-19
Y	US 4,443,350 A (MOLINA) 17 April 1984, see entire document.	1-19

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/07524

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

C08K 3/10

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

524/435; 428/402, 447, 900

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

524/435; 428/402, 447, 900

B. FIELDS SEARCHED
Electronic data bases consulted (Name of data base and where practicable terms used):

APS:
Search Terms: magnetic pad, particulate, silicone; coating